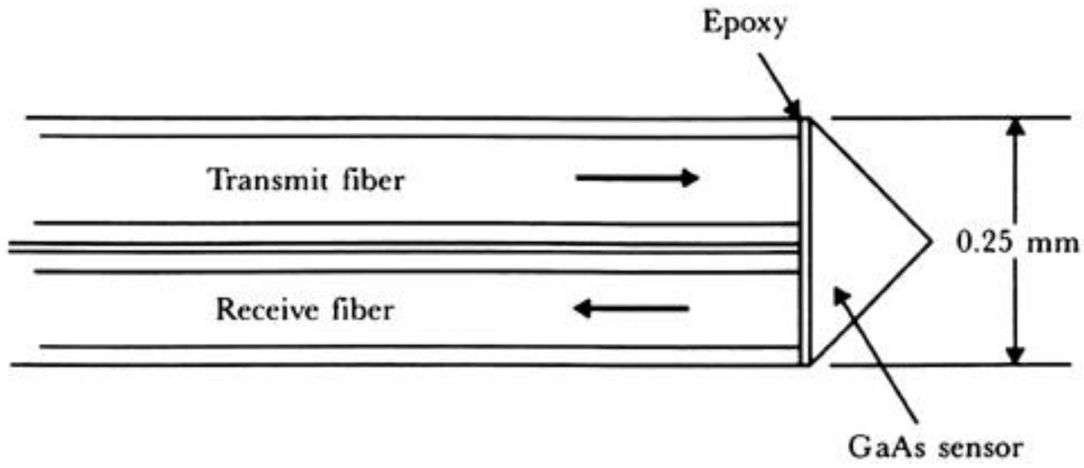
EIPC
NEE-403
Unit-2
Opto-electronic TRANSDUCERS

Fiber-Optic Temperature Sensors

- Small and compatible with biological implantation.
- Nonmetallic sensor so it is suitable for temperature measurements in a strong electromagnetic heating field.



Gallium Arsenide (GaAs) semiconductor temperature probe.

The amount of power absorbed increases with temperature

Optical Measurements

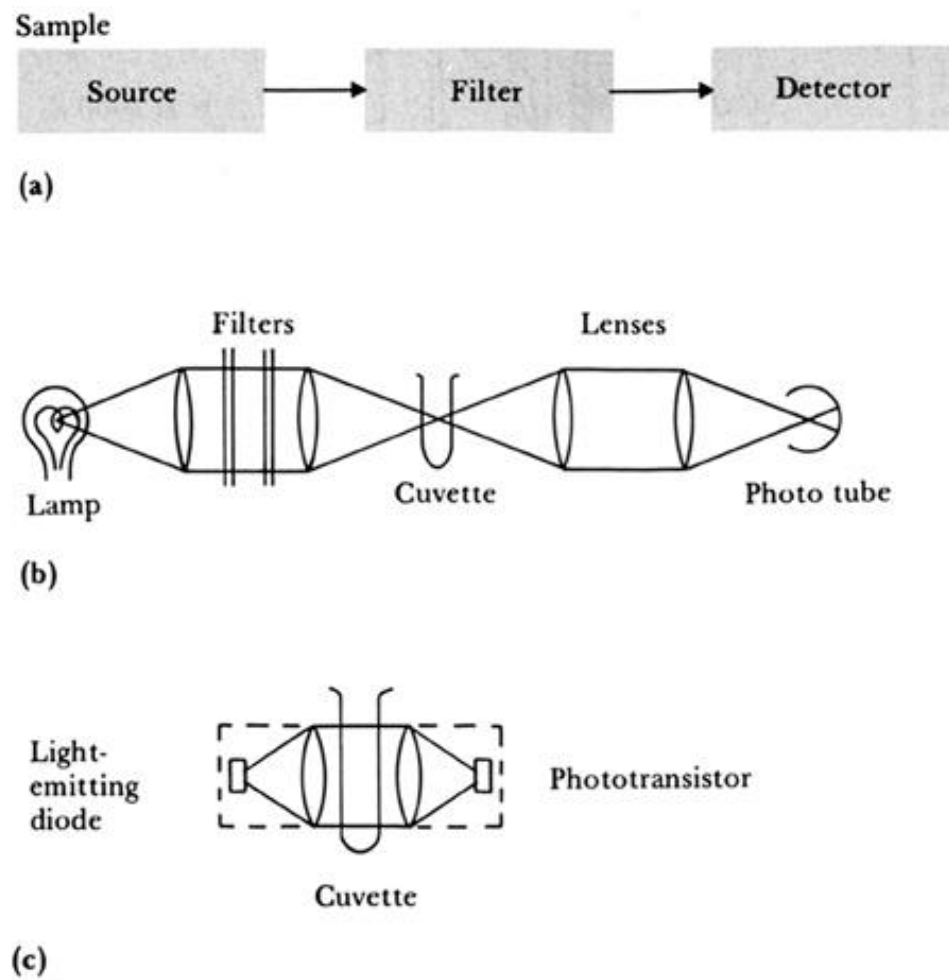
Applications:

1- Clinical-chemistry lab (analyze sample of blood and tissue)

2- Cardiac Catheterization (measure oxygen saturation of hemoglobin and cardiac output)

Components:

Sources, filters, and detectors.

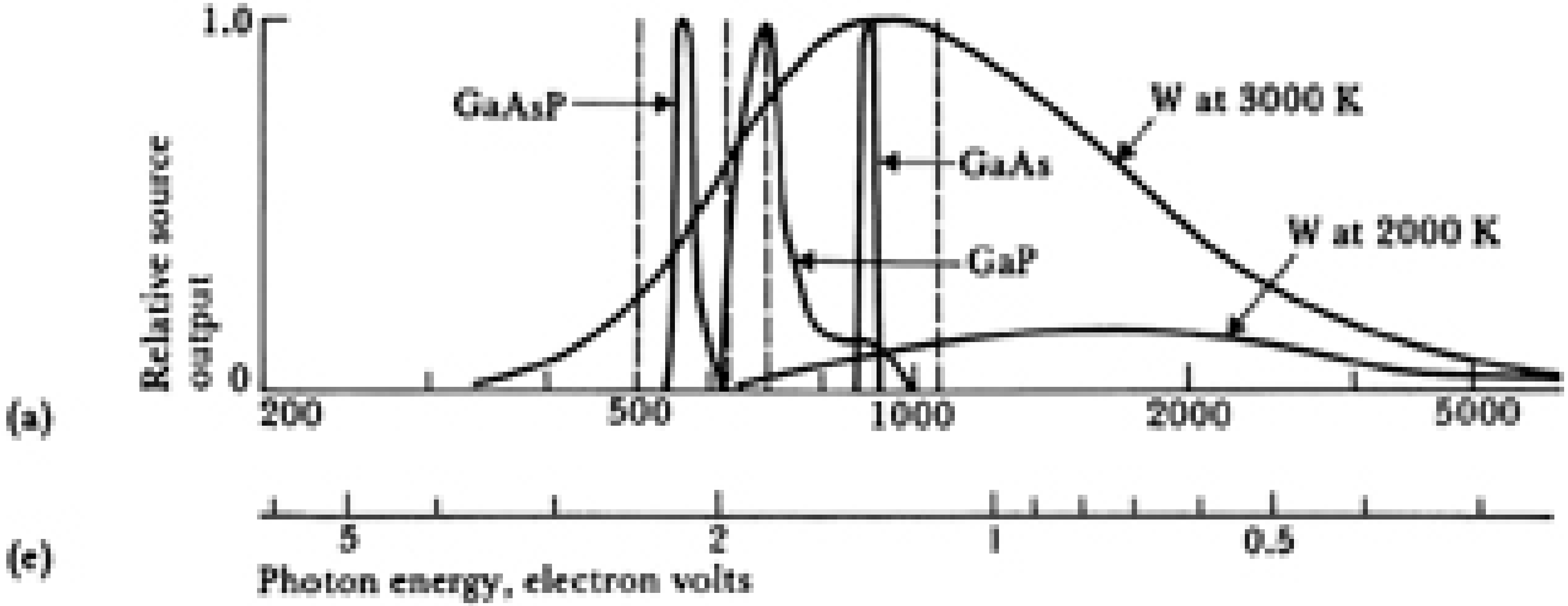


General block diagram of an optical instrument. (b) Highest efficiency is obtained by using an intense lamp, lenses to gather and focus the light on the sample in the cuvette, and a sensitive detector. (c) Solid-state lamps and detectors may simplify the system.

Radiation Sources

1- Tungsten Lamps

- Coiled filaments to increase emissivity and efficiency.
- Ribbon filaments for uniform radiation
- Tungsten-halogen lamps have iodine or bromine to maintain more than 90% of their initial radiant.



Spectral characteristics of sources, (a) Light sources, Tungsten (W) at 3000 K has a broad spectral output. At 2000 K, output is lower at all wavelengths and peak output shifts to longer wavelengths.

Radiation Sources

2- ARC Discharges

- Low-pressure lamp: Fluorescent lamp filled with Argon-Mercury (Ar-Hg) mixture. Accelerated electron hit the mercury atom and cause the radiation of 250 nm (5 eV) wavelength which is absorbed by phosphor. Phosphor will emits light of longer visible wavelengths.
- Fluorescent lamp has low radiant so it is not used for optical instrument, but can be turned on in 20 μsec and used for tachistoscope to provide brief stimuli to the eye.
- High pressure lamp: mercury, sodium, xenon lamps are compact and can provide high radiation per unit area. Used in optical instruments.

Radiation Sources

3- Light-Emitting Diodes (LED)

A *p-n* junction devices that are optimized to radiant output.

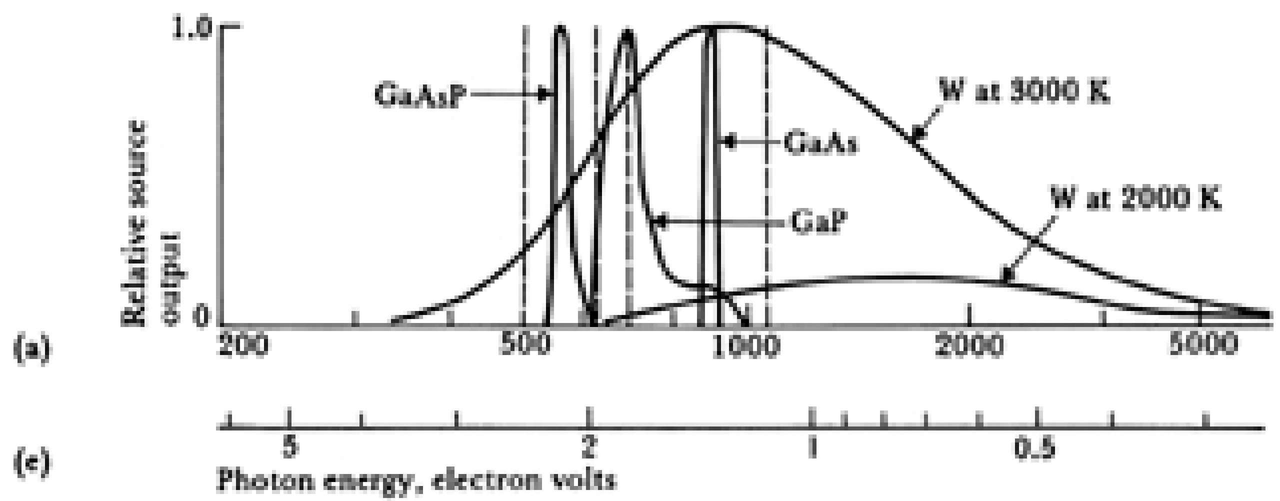
-GaAs has a higher band gap and radiate at 900 nm. Switching time 10 nsec.

-GaP LED has a band gap of 2.26 eV and radiate at 700 nm

-GaAsP absorb two photons of 940 nm wavelength and emits one photon of 540 nm wavelength.

Advantages of LED: compact, rugged, economical, and nearly monochromatic.

Spectral characteristics of sources, (a) Light-emitting diodes yield a narrow spectral output with GaAs in the infrared, GaP in the red, and GaAsP in the green.

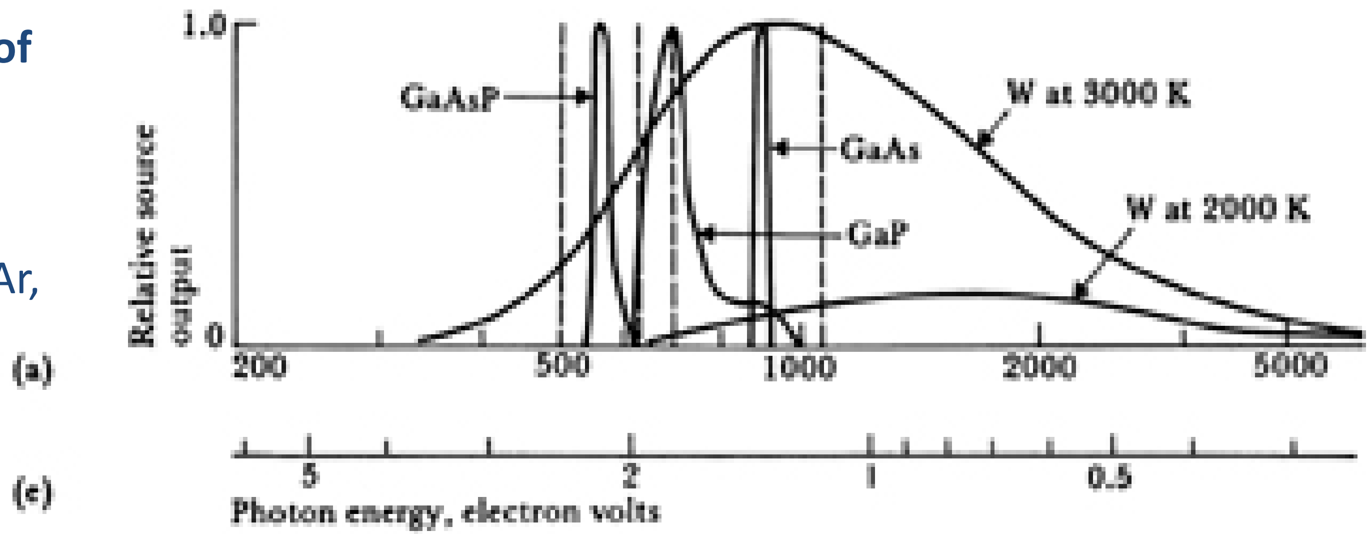


Radiation Sources

4- Laser (Light Amplification by Stimulated Emission of Radiation)
-He-Ne lasers operate at 633 nm with 100 mW power.
-Argon laser operates at 515 nm with the highest continuous power level with 1-15 W power.
-CO_2 lasers provide 50-500 W of continuous wave output power.
-Ruby laser is a solid state lasers operate in pulsed mode and provide 693 nm with 1-mJ energy.

The most medical use of the laser is to mend tear in the retina.

Spectral characteristics of sources, (a) Monochromatic outputs from common lasers are shown by dashed lines: Ar, 515 nm; HeNe, 633 nm; ruby, 693 nm; Nd, 1064 nm



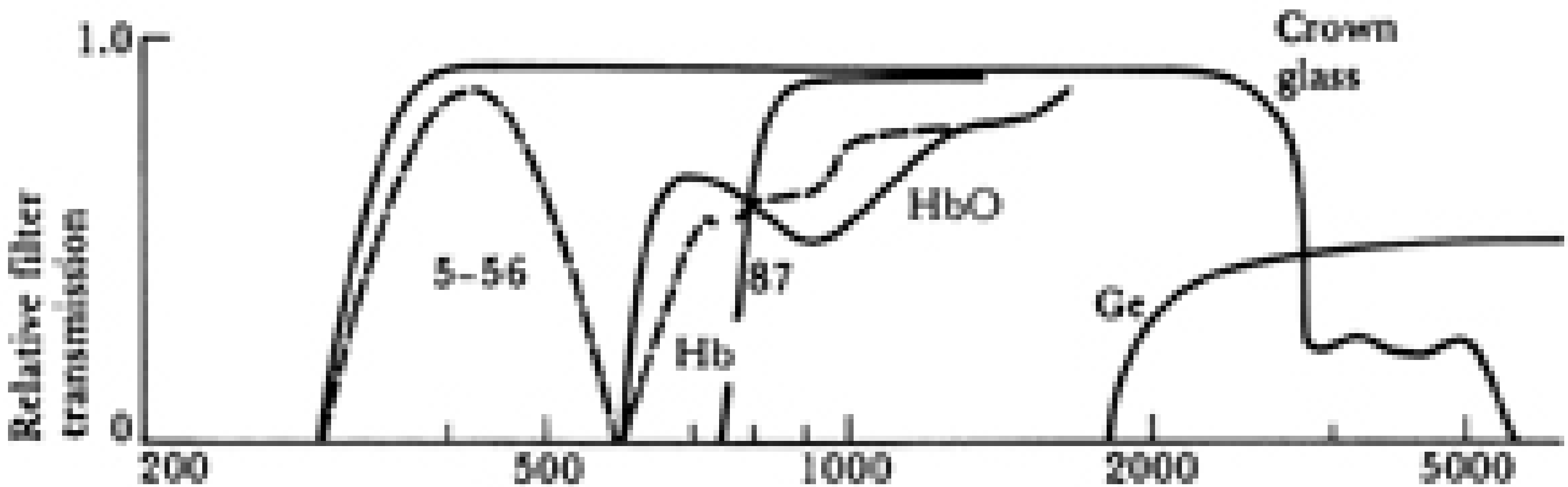
Optical Filters

- Optical filters are used to control the distribution of radiant power or wavelength.
- **Power Filters**
  - Glass partially silvered: most of power are reflected
  - Carbon particles suspended in plastic: most of power are absorbed
  - Two Polaroid filters: transmit light of particular state of polarization
- **Wavelength Filters**
  - Color Filters: colored glass transmit certain wavelengths
  - Gelatin Filters: a thin film of organic dye dried on a glass (Kodak 87) or combining additives with glass when it is in molten state (corning 5-56).
  - Interference Filters: Depositing a reflective stack of layers on both sides of a thicker spacer layer. LPF, BPF, HPF of bandwidth from 0.5 to 200nm.
  - Diffraction grating Filters: produce a wavelength spectrum.

Optical Filters

Spectral characteristics of filters (b) Filters. A Corning 5-65 glass filter passes a blue wavelength band. A Kodak 87 gelatin filter passes infrared and blocks visible wavelengths. Germanium lenses pass long wavelengths that cannot be passed by glass. Hemoglobin Hb and oxyhemoglobin HbO pass equally at 805 nm and have maximal difference at 660 nm.

(b)



Optical method for measuring fat in the body (fat absorption 930 nm
Water absorption 970 nm

Classifications of Radiation Sensors

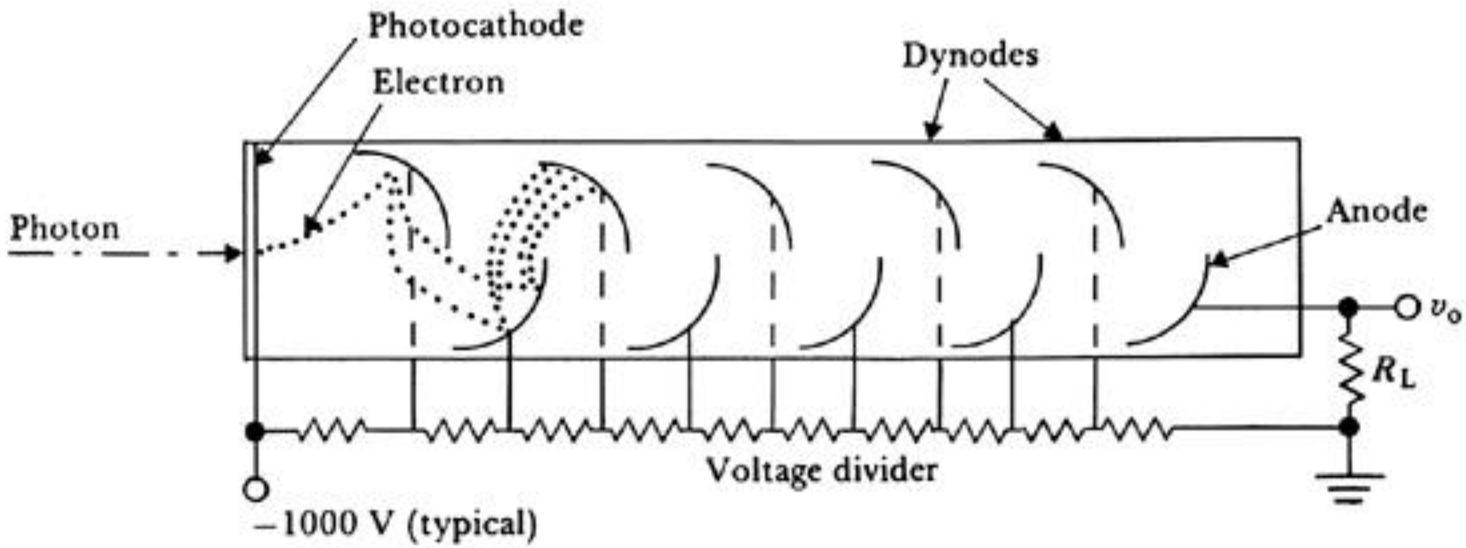
- **Thermal Sensors**:
- absorbs radiation and change the temperature of the sensor.
  - Change in output could be due to change in the ambient temperature or source temperature.
  - Sensitivity does not change with wavelength
  - Slow response

  Example: Pyroelectric sensor: absorbs radiation and convert it to heat which change the electric polarization of the crystals.
- **Quantum Sensors**:
- absorb energy from individual photons and use it to release electrons from the sensor material.
  - sensitive over a restricted band of wavelength
  - Fast response
  - Less sensitive to ambient temperature

  Example: Eye, Phototube, photodiode, and photographic emulsion.

Photoemissive Sensors

Phototube: have photocathode coated with alkali metals. A radiation photon with energy cause electron to jump from cathode to anode.
Photon energies below 1 eV are not large enough to overcome the work functions, so wavelength over 1200nm cannot be detected.



Photomultiplier An incoming photon strikes the photocathode and liberates an electron. This electron is accelerated toward the first dynode, which is 100 V more positive than the cathode. The impact liberates several electrons by secondary emission. They are accelerated toward the second dynode, which is 100 V more positive than the first dynode, This electron multiplication continues until it reaches the anode, where currents of about 1 μA flow through R_L. Time response < 10 nsec

Photoconductive Cells

- Photoresistors: a photosensitive crystalline materials such as cadmium Sulfide (CdS) or lead sulfide (PbS) is deposited on a ceramic substance.

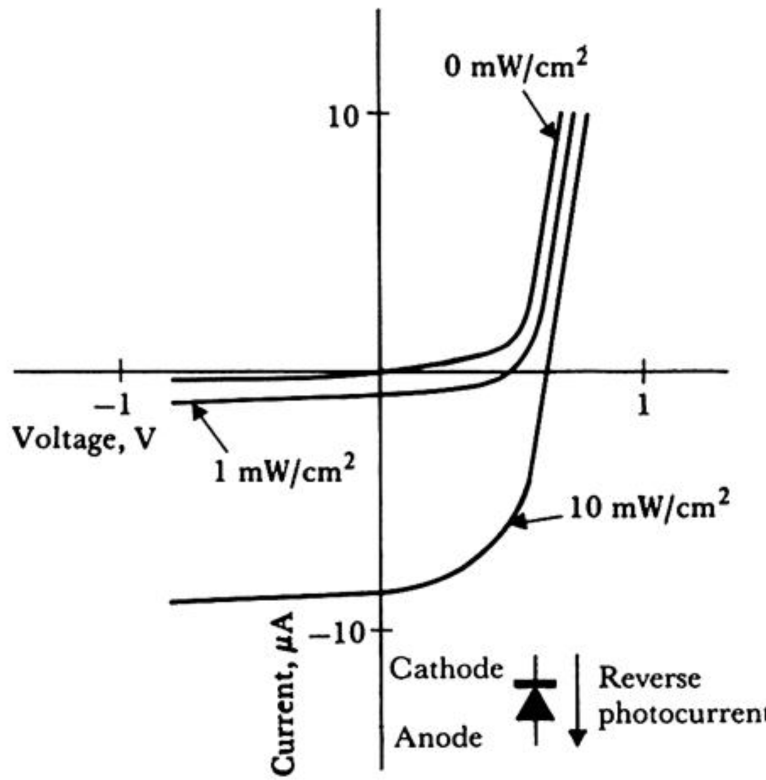
- The resistance decrease of the ceramic material with input radiation. This is true if photons have enough energy to cause electron to move from the valence band to the conduction band.

Photojunction Sensors

Photojunction sensors are formed from *p-n* junctions and are usually made of silicon. If a photon has enough energy to jump the band gap, hole-electron pairs are produced that modify the junction characteristics.

Photodiode: With reverse biasing, the reverse photocurrent increases linearly with an increase in radiation.

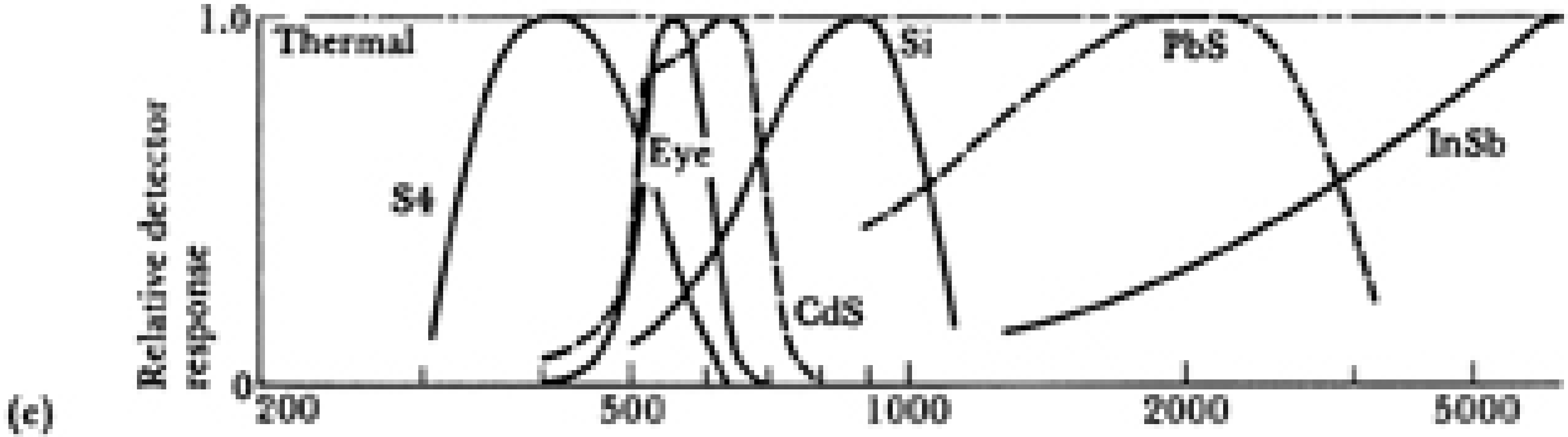
Phototransistor: radiation generate base current which result in the generation of a large current flow from collector to emitter.
Response time = 10 microsecond



Voltage-current characteristics of irradiated silicon p-n junction. For 0 irradiance, both forward and reverse characteristics are normal. For 1 mW/cm^2, open-circuit voltage is 500 mV and short-circuit current is 8 μA.

Photovoltaic Sensors

Photovoltaic sensors is a *p-n* junction where the voltage increases as the radiation increases.



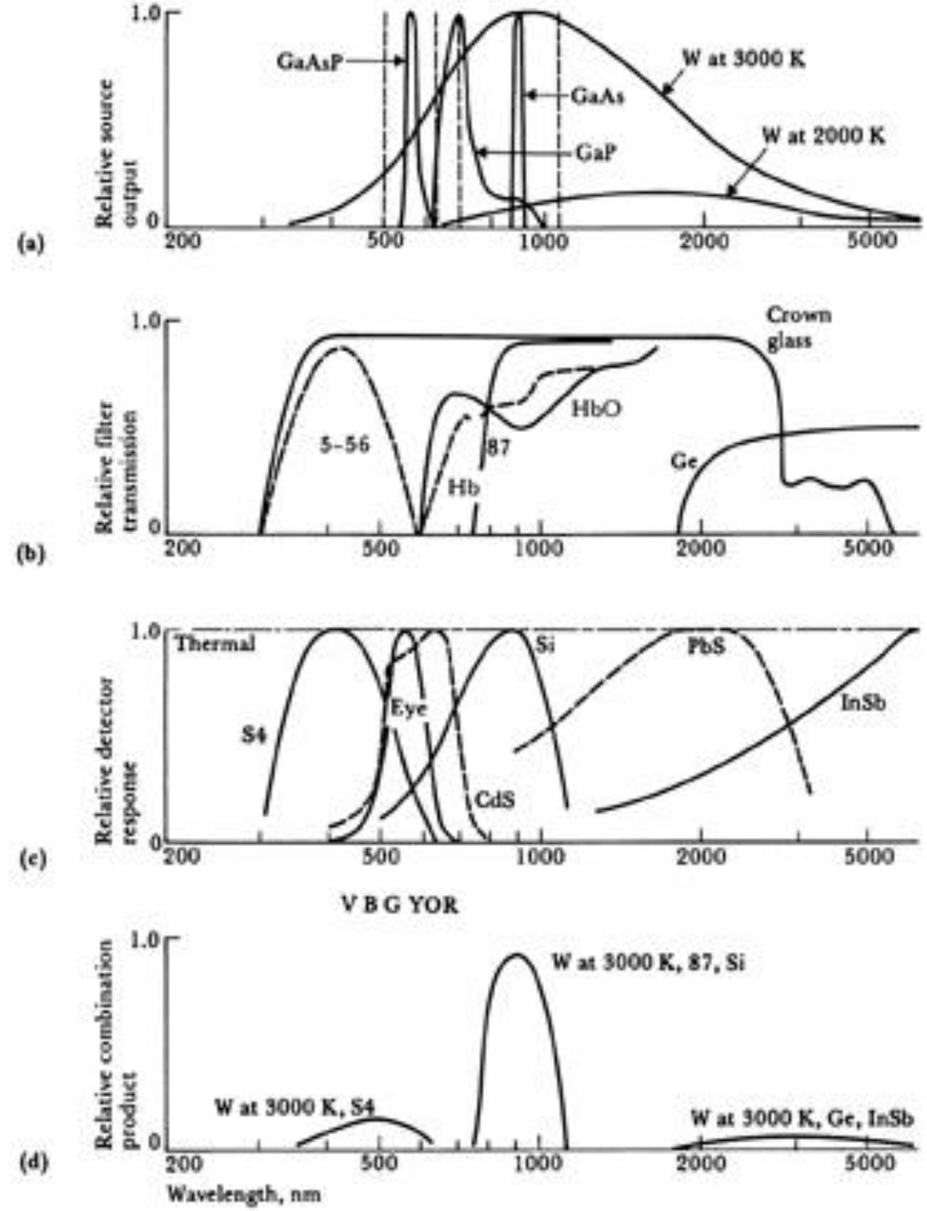
Spectral characteristics of detectors, (c) Detectors. The S4 response is a typical phototube response. The eye has a relatively narrow response, with colors indicated by VBGYOR. CdS plus a filter has a response that closely matches that of the eye. Si p-n junctions are widely used. PbS is a sensitive infrared detector. InSb is useful in far infrared. Note: These are only relative responses. Peak responses of different detectors differ by 107.

Optical Combinations

Total effective irradiance, is found by breaking up the spectral curves into many narrow bands and then multiplying each together and adding the resulting increments.

$$E_e = \sum S_\lambda F_\lambda D_\lambda \Delta\lambda$$

S_λ= relative source output;
F_λ= relative filter transmission
D_λ= relative sensor responsivity



Spectral characteristics of combinations thereof (d) Combination. Indicated curves from (a), (b), and (c) are multiplied at each wavelength to yield (d), which shows how well source, filter, and detector are matched.

Thank You